

essential to, or the determining cause of, the formation of a cyclonic whirl. He finds that it is not necessary and gives in detail the facts of a special case over the Bay of Bengal between the 1st and 15th of December, 1894. His conclusions are favorable to the general correctness of the ideas developed by Professor Ferrel who, as is well known, gave a more precise expression to the principles taught by Espy. According to these meteorologists, when a general uniformity of pressure and quietness prevails in the atmosphere, especially over the ocean, and when the quiet air becomes so warm and moist that ascending currents and clouds are forming here and there over the warm region, then any one of these ascending currents may be so fed with moist air as to steadily increase in its volume and instability; it rises and the surrounding air that is drawn in begins a gyratory motion, usually in the cloud regions, but which is soon propagated downward to the earth's surface. The quiet region in which the instability first occurs is often that which is called the doldrums; if this is not located at the equator, but five or ten degrees north or south, depending on the season, then the gyration of the winds around the center is fully determined by the deflecting action resulting from the diurnal rotation of the earth on its axis.

In summing up the results of his study of this storm Mr. Dallas says:

On the first three days of December, 1894, the Indian daily weather charts exhibited a typical illustration of the ordinary meteorological conditions which theory assigns to the Belt of Calms. An area of continuous low barometer lay over the equator, on either side of which the two trade wind currents blew freshly, while within the area itself, the surface winds were very light and variable. The weather was fine generally, but daily, at 4 p. m., just after the diurnal period of greatest evaporation, heavy precipitation of rain took place. The charts for these days show, then, a more or less inclosed area within which the weather was fine, and constant evaporation was proceeding with apparently no horizontal outlet for the accumulating aqueous vapor. On the 3d of December the southeast trades seemingly began to take off, but the observations on this day show that nearly all the ships in southern latitudes had entered or were close to the inclosed area of light and unsteady winds and low barometer. The sky was densely clouded, and though heavy rain fell for a time during the later hours of the day, this outlet was probably insufficient to stay the steady accumulation of aqueous vapor over the inclosed area. In the afternoon of this day (3d) the vessel *Falls of Garry*, in latitude 5° south, reported the cessation of the southeast trades, their replacement by light, variable, "puffy" breezes and heavy rain. By the 4th the process of accumulation of aqueous vapor had apparently reached its maximum and the subsequent condensation had set in. A continuous downpour of rain was reported, and this was accompanied with light, variable airs and calms on all the ships within the inclosed area. At the same time as the constant rapid condensation proceeded so did atmospheric pressure diminish, so that by the morning of the 6th a well-defined central area of depression had been developed within the inclosed area almost directly over the equator. It is interesting to note that so far as can be judged from the observations, at the period when the process of constant evaporation had resulted in a saturated condition of the atmosphere over the inclosed area, and the subsequent process of sudden, rapid, and extensive condensation had succeeded, there apparently occurred a slight but appreciable rise of pressure over the whole equatorial region under observation. This rise was shown by the chart of 8 a. m. of the 4th (not reprinted), and it will be remembered that it was after 4 p. m. on the 3d that the process of rapid condensation set in and became the most important of the changes in progress over the area.

If the above be the explanation of the initiation of the storm, then further inquiry would be unnecessary, as the principle of evaporation and condensation is a general and not a local one and is as applicable to equatorial regions as to other parts of the earth's surface. Further, it is unnecessary from this point of view to introduce a force to account for the gyratory motions, as the theory presupposes an irregular inflow of the surrounding air as pressure diminishes, an inflow which can only result in a vortical or spiral motion of the atmosphere converging towards a center, while for the gradual increase in the intensity of the barometric depression and in the force of the winds an adequate cause is assigned in the rapid condensation and precipitation of rain accompanying the inflowing currents of air when once the center is developed. \* \* \* Two minor points of interest connected with the disturbance deserve perhaps passing notice. The first is the torrential rain which accompanied the disturbance throughout its course. This rainfall was apparently associated with a stream of air from trans-equatorial regions, and as soon as this supply was cut off and the wind

shifted to northeast again, to the south of the disturbance the rainfall decreased and the intensity of the disturbance diminished. The second is the sharply defined limits of the disturbance. Hardly any indication of the presence of a storm was afforded by the coast observations. So much so indeed was this the case that the rainfall which occurred around the head of the Bay on the 14th and 15th when the center of disturbance was in latitude 18° and 20° N was ascribed to disturbed weather in Upper India instead of its actual source, viz, the depression over the Bay.

#### THE LOW AREAS ON OUR PACIFIC COAST.

The daily chart for the Northern Hemisphere accompanying the Bulletin of International Simultaneous Meteorological Observations, 1875-1887, has long since familiarized the student with the fact that areas of low pressure frequently pursue very long paths for many consecutive days, in their circuit around the north temperate regions. Those that start in the equatorial portions of the Atlantic or Pacific, after passing northwest and curving to the northeast, finally move east-northeastward between the forty-fifth and sixty-fifth parallels. Others start in the temperate regions, and, without moving to the westward or recurving, pursue nearly the whole path in an east-northeast direction. In describing the history of areas of low pressure the authors who have contributed these chapters to the successive MONTHLY WEATHER REVIEWS for nearly twenty-five years past have usually kept in mind the fact that lows which first appear in Washington, Oregon, Montana, and Alberta, or British Columbia, have probably originated at some point far to the west, and if occasionally the description of such a storm begins by speaking of it as originating over our North Pacific Slope Region; this is a slip of the pen which the reader may generally interpret without being misled by it.

The Editor has on several occasions pointed out the fact that the isobars and therefore the winds at a considerable distance above the earth's surface have very little resemblance to the isobars and winds at sea level. In fact, the normal isobars at an elevation of 5,000 meters (which represents a surface a little above the summits of the Rocky Mountains) present a grand oval depression whose longest axis extends from the United States toward the north-northwest over the Saskatchewan and the Arctic regions to eastern Siberia. (See Chart VII, herewith.) By studying a polar projection of the Northern Hemisphere we perceive that the whole upper circulation of winds and clouds and the general movement of areas of low pressure and high pressure are related to this distribution of pressure in the upper layers of air. When a storm center moves from Japan to the North Pacific, or from the latter to our Pacific Coast, or from Alberta and Oregon southeastward, or from Texas and Kansas northeastward, it is describing some portion of a circuit about this great upper region of low pressure. It is simply a special whirl gliding about in the maelstrom that occupies one-half of the northern hemisphere. The axis of this oval polar maelstrom probably changes its position with considerable regularity, oscillating slowly to and fro; therefore, the paths which the smaller disturbances describe will vary simultaneously with that; sometimes the storms will move far to the south either in America or in Russia in order to circumnavigate the southern extension of the longer axis of the oval but will thereby diminish in intensity and almost die out. Sometimes a new whirl will start at the southern end of the oval; sometimes all the paths of the low areas will lie on the northern border of the United States and Canadian weather charts because the polar maelstrom has altered its dimensions and locations. Even the great subpermanent areas of low pressure in the North Atlantic and North Pacific are subordinate to the greater area of low pressure at the upper level and its attendant winds.

These remarks are appropriate to a note from Mr. Alexander McAdie, local Forecast Official at San Francisco, in which he says:

A little study of weather types on the Pacific Slope makes it plain that certain conditions traverse the country from the Pacific; thus to take at random the month of January, 1895, some of the deep lows that might have been supposed to originate over Manitoba or further west over Assiniboia, Alberta, and British Columbia, did not so originate but are storms that can be traced distinctly in their onward march from the northern-central Pacific Ocean northeastward, often recurring and doubling in their paths, but preserving identity. Passing south of Sitka they march eastward and reach Newfoundland in about 120 hours. For example, a storm passed from Sitka to St. Johns between January 12 and 17. This storm did *not* originate in the Northwest Territory but clearly came in from the Pacific. Where it did originate we do not know, but it is an error to locate its origin in any of the Northwest Territories. And this is probably true of most storms which are said to originate over Athabasca or Saskatchewan. The truth is that storms first come into notice in these localities but originate elsewhere.

In preparing the chapter on high and low areas for the MONTHLY WEATHER REVIEW for January, 1895, Mr. A. J. Henry (whose name in the absence of the Editor was accidentally omitted in that connection) makes note on page 3 of the fact that:

The storms of the Pacific Coast present a characteristic that is worthy of special study, viz, an apparent oscillation from the ocean to the land, and *vice versa*, that is to say, the low approaches the coast and partially disappears, reappearing within a period of twelve to thirty-six hours, and continuing this action until the storm finally disappears.

This same phenomenon has recently been independently noted by Mr. W. H. Hammon, Forecast Official, Weather Bureau at San Francisco, who, under date of November 14, states that:

During the past two years I have been engaged during my leisure time in preparing weather charts of the Pacific Ocean. Some remarkable information has been obtained from these charts. The storms that approach the Pacific Coast from the ocean, frequently recur several times after touching the coast, the number of such oscillations being greater the farther south the storm approaches the coast.

The fact that a storm moves southward, ricocheting along the Pacific Coast, and probably dying away as it progresses, harmonizes with the general theory of the movement of vortices. If the general distribution of pressure at sea level, and especially at 16,000 feet, is such as to give the storm center a general movement southward or southeastward along the Pacific Coast, then the influences of the high mountain land in the interior of California and of the plateau lands of Idaho, Nevada, Oregon, Utah, and Arizona are like those of a barrier against which a small atmospheric vortex may strike only to be reflected several times in succession. A further special influence of these high lands is to furnish descending dry air whose mixture with the moist air of the whirlwind rapidly diminishes the quantity of condensation and the sustaining power of the whole mechanism. The inverse conditions prevail on the east slope of the Rocky Mountains, where, therefore, a whirl once started is apt to increase in all characteristic phenomena. Possibly this process is illustrated by the low area of October 29, 1886, in regard to which Mr. McAdie writes:

On Monday, October 26, a. m., a low, 26.70, with southeast winds, appeared on the Oregon coast. Taking a most unusual course this storm passed southward, and on the morning of the 27th was over central California (San Francisco, 29.56, southeast wind, 1.10 inches rainfall). By 10 o'clock of the same day the storm was moving up the San Joaquin Valley, and heavy rain was falling over southern California. On the morning of the 28th the pressure was 29.78 at El Paso, with rain, and the storm was out of our limits of observation, but just coming into prominence elsewhere. Its subsequent history is plain.

#### HIGH-LEVEL ISOBARS.

In a preceding note the Editor has remarked that the movements of low areas across North America are elucidated by studying the upper isobars of the Northern Hemisphere. Maps of these isobars would doubtless be more frequently constructed and studied were we not hindered by the apparent uncertainty of reducing pressures observed at a low level upward to some considerable altitude; especially might one be hindered by the great labor of computing many such reduc-

tions. A rigorously correct reduction upward requires that we know the average temperature of the column of air above each station, and this is practically impossible in the present state of meteorology, though it may become practicable when balloons and kites have been more widely utilized. Meanwhile we must be content with rather crude approximations, but this will not lead us astray if we keep clearly before us the extent to which our data are liable to be in error. The preparation of a daily chart of upper isobars, say for 8 a. m. and 8 p. m., standard time, could hardly be seriously undertaken unless we had actual observations of the upper temperatures from balloons or kites or mountain peaks, but the preparation of monthly and annual normal charts for the level of 5,000 meters may, perhaps, be undertaken with satisfactory success at the present time. The laborious numerical computations of the pressures at this upper level can be entirely avoided by using the very convenient method suggested by Moeller in 1882, and elaborated by Koeppen in the *Met. Zeitschrift* for December, 1888. By omitting illusory refinements Koeppen has thrown all the labor into the use of a single table, which he gives in metric measures. The following table reproduces in English measures the second of the tables given by Koeppen.

#### Atmospheric pressure at 5,000 meters, or 16,404 feet.

[The arguments are: Pressure at sea level, and the average temperature of the intervening layer of air, which is approximately the actual temperature at 2,500 meters.]

Column temperatures (Fahrenheit).	Sea-level pressure (inches).									
	27.99	28.37	28.74	29.13	29.52	29.92	30.32	30.73	31.14	
°	<i>Ins.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>Ins.</i>	
75.2	15.82	16.04	16.25	16.47	16.69	16.92	17.15	17.37	17.61	
63.7	15.61	15.82	16.04	16.25	16.47	16.69	16.92	17.15	17.37	
52.7	15.41	15.61	15.82	16.04	16.25	16.47	16.69	16.92	17.15	
42.1	15.20	15.41	15.61	15.82	16.04	16.25	16.47	16.69	16.92	
32.0	15.00	15.20	15.41	15.61	15.82	16.04	16.25	16.47	16.69	
21.9	14.80	15.00	15.20	15.41	15.61	15.82	16.04	16.25	16.47	
12.2	14.61	14.80	15.00	15.20	15.41	15.61	15.82	16.04	16.25	
3.0	14.41	14.61	14.80	15.00	15.20	15.41	15.61	15.82	16.04	
-6.0	14.22	14.41	14.61	14.80	15.00	15.20	15.41	15.61	15.82	
-14.8	14.03	14.22	14.41	14.61	14.80	15.00	15.20	15.41	15.61	
-23.3	13.85	14.03	14.22	14.41	14.61	14.80	15.00	15.20	15.41	
-31.4	13.66	13.85	14.03	14.22	14.41	14.61	14.80	15.00	15.20	
-39.1	13.48	13.66	13.85	14.03	14.22	14.41	14.61	14.80	15.00	
-46.7	13.30	13.48	13.66	13.85	14.03	14.22	14.41	14.61	14.80	
-53.9	13.13	13.30	13.48	13.66	13.85	14.03	14.22	14.41	14.61	

This table is so arranged that the same pressure at the upper level, for instance 16.25 inches, is repeated as we proceed downward and to the right; that is to say, there is a series of pairs of sea-level pressures and column-temperatures that will reproduce the same upper level pressure, *e. g.*, 75.2° and 28.74 inches; 63.7° and 29.13 inches; 52.7° and 29.52 inches, etc. In other words, a lower column-temperature may so counterbalance a higher sea-level pressure as to give the same upper-level pressure. One method of using this table consists in picking out by interpolation the upper reduced pressure for any given column temperature and sea level pressure, but this would be very laborious on account of the double interpolation, even if our little table were enlarged tenfold. By far the most expeditious method of applying Koeppen's table was suggested by Moeller and is as follows: Let there be given a chart of sea-level isobars and isotherms; assume a rate of upward diminution of air temperature and calculate how much this would amount to in 2,500 meters; subtract this amount from the temperatures inscribed at the end of our sea-level isotherms, and they at once become isotherms for the level of 2,500 meters, that is to say, they represent the average temperature of a layer 5,000 meters thick, or the argument that appears in the left-hand column of the above table. We now draw another set of 2,500 meter isotherms, which are interpolated between those already drawn, so as to exactly represent the column-temperatures, 75.2° F., etc., as given in the above table. In a similar way we now draw a second set of sea-level